AD 419289

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA

UNCLASSIFIED

ENGINEER MANUAL

EM 1110-345-515

1 MARCH 1963

ENGINEERING AND DESIGN

64-5

WATER SUPPLY - EMERGENCY CONSTRUCTION

HEADQUARTERS, DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS

HEADQUARTERS
DEPARTMENT OF THE ARMY
Office of the Chief of Engineers
Washington 25, D. C.

Manual
No. 1110-345-515

1 March 1963

ENGINEERING AND DESIGN

WATER SUPPLY - EMERGENCY CONSTRUCTION

Table of Contents

SECTION I - GENERAL

This manual rescinds Engineering Manual for Emergency Construction, Chapter VI, January 1951 (EM 1110-345-515).

Paragraph		Page

SECTION III - METHODS FOR SPECIAL WATER TREATMENT

Paragraph		Page

SECTION IV - WATER-STORAGE TANK

SECTION V - DISTRIBUTION SYSTEM

SECTION I - GENERAL

1-01. PURPOSE AND SCOPE. This manual prescribes the procedures to be followed in the utilization of existing water supplies, the development and purification of ground- and surface-water supplies, and water distribution and storage, in connection with emergency projects. Good engineering practice will be followed in the absence of specific instructions covering special conditions and problems. This manual is applicable to all elements of the Corps of Engineers responsible for Army and Air Force construction.

1-02. DESIGN PROCEDURE. Planning for the development of the water-supply system for any project will proceed simultaneously with the planning for other facilities to insure proper coordination. The final design of the distribution system must, of necessity, await the final site plan and the completion of field surveys to obtain the necessary topography. The development of ground-water supplies, the design of surface-supply works and filtration plants, and the design of water-distribution systems are highly specialized and require the attention of engineers experienced in this type of work.

1-03. CONSERVATION OF CRITICAL MATERIALS. Current policies of the Department of Defense with respect to the conservation of critical materials must be strictly observed in development of water supply, and the design of water-treatment plants, water distribution, and storage works. Water-purification plants will be simplified as much as possible and preference given to designs that require the use of a minimum amount of mechanical equipment and items of critical material. To avoid delays in securing delivery of equipment, every effort will be made to utilize types of equipment that can be supplied by several manufacturers. The ability of equipment manufacturers to make delivery within the time required will be carefully investigated prior to making a commitment for the purchase of mechanical equipment.

1-04. DEFINITIONS.

Waterworks. All construction for the collection, transportation, pumping, treatment, storage, and distribution of water.

Supply Works. Dams, impounding reservoirs, intake structures, pumping station, wells, and all other construction for the development of a source of water supply.

Supply Line. The pipeline from the source of supply to the treatment works or the distribution system.

Treatment Works. Filtration plant, reservoirs, and all other construction required for the treatment of a water supply.

Distribution System. The pipeline throughout the building areas including hydrants, valves, and other appurtenances used to supply water for domestic and fire-fighting purposes.

Feeder Mains. The principal pipelines of the distribution system.

Distribution Mains. The pipelines that comprise the distribution system.

Service Lines. Small pipelines connecting buildings to distribution mains.

Effective Population. This includes military personnel and their dependents and civilians and their dependents living on the station or in adjacent housing or similar projects, supplied by station utilities. The authorized population also includes the nonresident civilian employees. In general, nonresidents are allowed 50 gallons per day compared to 150 gallons per day for residents. Therefore, an effective-population figure can be obtained by adding one-third of the figure for nonresidents to the figure for residents. The use of this effective-population figure will simplify all subsequent calculations.

Capacity Factor. The mathematical value, varying inversely with the magnitude of the population, which is applied to the effective-

population figure to provide for reasonable increases in population, variations in water demands and uncertainties as to actual water-supply requirements, and for unusual peak demands, the magnitude of which cannot be accurately estimated in advance.

Design Population. The population figure obtained by multiplying the effective-population figure by the proper capacity factor.

Required Daily Demand. The total daily water-supply requirement. This is obtained by multiplying the design population by the per capita domestic water allowances, and adding to this quantity any special industrial, aircraft-wash, irrigation, air-conditioning, or other demands. Other demands include the amount necessary to replenish, in 48 hours, the storage required for fire protection and normal operation. Where the supply is from wells, the quantity available in 48 hours of continuous operation of the wells will be used in calculating the total supply needed for replenishing storage and maintaining fire and domestic demands and industrial requirements that cannot be curtailed.

Fire Flow. The amount of water in gallons per minute required at a specific residual pressure at the site of the fire for a specific period of time.

Fire Demand. The amount of water in gallons per minute required during specified fire period. The fire demand is determined by the sum of the fire flow, 50 percent of the average domestic-demand rate, and any industrial demand that cannot be reduced during a fire period. The residual pressure is specified for either the fire-flow or essential industrial demand, whichever is the higher. Fire demand will include quantities required for automatic-sprinkler operation, in addition to direct hydrant fire-flow demand as appropriate, when sprinklers are served directly by the water-supply system.

1-05. DOMESTIC-WATER REQUIREMENTS. In the design of the water-supply system, the quantities indicated in table I will be used for the domestic-water allowances in determining the capacity of the water-supply system:

Table I - Domestic-Water Allowances for Emergency Projects

Type of Project	Daily Allowance
Armored divisions	150 gal. per capita
Air Force units	150 gal. per capita
Hospital units	150 gal. per bed
Hospital resident personnel not otherwise provided for (60% of No. of beds)	100 gal. per capita
Hotels and similar facilities converted to troop housing	70 gal. per capita
Other military-type projects:	100 gal. per capita
Civilian employees	30 gal. per employee per shift
Civilian residents	100 gal. per capita
Industrial & special projects	As determined for individual projects

Note: The allowances set forth above include water used for laundries to serve the resident personnel, washing vehicles, limited watering of planted and grassy areas, and similar uses.

1-06. FIRE-FLOW REQUIREMENTS. In the design of the water-supply system, the quantities indicated in table II will be used for the fire flow in determining the capacity of the water-supply system:

Table II - Fire-Flow Requirements for Emergency Projects

Type of Project	Gallons per Minute Fire Flow: 1 Fire for 2 Hrs.	Gallons per Minute Fire Flow: 1 Fire for 4 Hrs.
Camps, cantonments, and Air Force installations:		
6,000 population or more		1,000
Warehouse area		2,000
1,000 to 5,999 population	1,000	
Warehouse area		1,000
300 to 999 population	500	
Less than 300 population	Fire flow incidental to domestic flow	
Dispersed layouts	500	
Station and general hospitals:		
500 or more beds		1,000
Less than 500 beds	1,000	
Port and storage projects:		
Warehouse area		2,000
Open-storage area		4,000

Tent or hutment camps:

For tent and hutment camps, it is necessary to provide fire protection only for warehouses, messhalls, latrines, and similar structures. Fire protection for these structures will be in accordance with the requirements set forth above.

Table II - Fire-Flow Requirements for Emergency Projects - continued

Type of Project

Plants:

As determined for individual projects.

Note: In computing the required fire flow, it will be assumed that a warehouse fire will not occur simultaneously with a fire in other areas.

1-07. SEPARATE FIRE-FLOW STORAGE. For storage and other projects requiring large fire-flow storage, an economic comparison between elevated storage and ground storage with fire pumps should be made. In some cases, the fire-flow requirements can most economically be met by providing the entire amount of water required for fire fighting in a ground-storage reservoir (500,000- or 1,000,000-gallon capacity) with sufficient gasoline-engine-driven fire pumps to deliver the required rate (2,000 or 4,000 g.p.m.). For flexibility of operation, the capacity of individual pumping units should not exceed 1,000 g.p.m. each, and the pressure at the pumps should not exceed 100 pounds per square inch. All fire pumps will be gasoline-engine-driven only and manually controlled. The system will be protected by pressure-relief valve discharging into the ground-storage reservoir. Elevated storage floating on the distribution system, in an amount equal to 25 gallons per capita, but not less than 50,000 gallons, will be sufficient for domestic requirements if elevated storage is necessary. If required, separate electric-motor-driven pumps will be installed to provide domestic service. If more than one ground reservoir is used, the connections to the reservoirs will be valved so that each may be taken out of service. Suction for the pumps may be through a common header with properly sized valve and connected to the ground reservoir to permit maximum flexibility of operation. Piping connections to the reservoir will depend upon source of supply and local conditions. The elevation of the site selected for the fire protection ground reservoir or reservoirs will be taken into account in determining the pressure at which water will be delivered by

the fire pumps. If the reservoir site is sufficiently elevated to provide the required 10-pound-per-square-inch residual pressure for the delivery of the fire flow to the point of use, pumps may be omitted. However, where it is proposed to omit pumps, a careful economic analysis will be made to determine that the delivery by gravity does not require larger mains, involving the use of more critical material than would be required if the low-level storage with pumping station were installed.

1-08. RELATIONSHIP BETWEEN DOMESTIC AND FIRE-FLOW DEMANDS. Each system must be analyzed to determine whether the capacities are fixed by the domestic requirements or by the fire demands. For camps, cantonments, Air Force installations, and other housing projects, the amount of the supply is fixed by the domestic requirements, and fire demands are generally supplied from storage. For port and storage projects, the amount of water supply may be fixed by the fire demands and if these are supplied entirely from storage, the supply should be sufficient to replenish the storage in 48 hours. Fire demands will usually govern in the design of distribution mains. These are designed to deliver the necessary fire-flow requirements plus 50 percent of the average domestic requirements.

1-09. CAPACITY OF WATER-SUPPLY SYSTEM.

a. Initial Design Capacity. The initial construction of the water-supply system will be based on the effective project population but will be increased by the following capacity factors:

Specified Project Population	Capacity Factor
5,000 and less	1.30
10,000	1.15
20,000	1.05
30,000 and more	1.00

Capacity factors determined by arithmetical interpolation will be used for intermediate project population figures.

Capacity factors will be applied to the supply works, supply lines, treatment works, principal feeder mains, and storage reservoirs. The capacity factors will be used in planning water supplies for all projects including general hospitals and prisoner of war camps.

The capacity factor will not be applied in determining distribution main sizes to serve areas that are fully developed and are not susceptible to further expansion. Capacity factors will not be used for hotels and similar structures that are acquired or rented for hospital and troop housing.

b. Capacity Factor. The capacity factor is applied by multiplying the effective population by the proper capacity factor stated above. This gives the design population, and the design of all elements of the system, except as noted above, should be based on the design population. The capacity factor will provide for the following:

Reasonable increases in population.

Variations in water demands and uncertainties as to actual water-supply requirements for projects of the same type.

Unusual peak demands, the magnitude of which cannot be accurately estimated in advance.

1-10. DESIGN ANALYSIS. A design analysis will be prepared for all projects in accordance with EM 1110-345-700. The design analysis will cover the following items if applicable to the project:

Water-Supply Facilities

Information concerning source (see Par. 2-03, 2-04, and 2-05).

Design population.

Basis for degree of treatment if any.

Basis for design of each unit.

Water-Storage Facilities

Method of determining storage requirements.

Basis for design of each unit.

Water-Distribution Systems

Design population.

Method of determining pipe sizes.

Typical design analyses are shown in Appendix III.

SECTION II - WATER SOURCES

2-01. GENERAL. The selection of a water supply will take into consideration availability, adequacy, quality, and cost of development. The supply that can be utilized at the lowest first cost is generally preferred, even though the total cost over a 5-year period may be higher when compared with the cost of developing and operating supplies from other sources. For projects located adjacent to fairly large cities, investigation will be made of the city's facilities to determine whether they are capable of supplying the projects and whether the city officials are favorably inclined toward serving the project at a reasonable cost to the Government. These investigations will take into consideration any increase in the city's requirements by reason of the construction of the Government facility. In cases where a long supply line is required between the source of supply and the distribution system, a study will be made of the economic size of main, taking into consideration the cost of construction, expected length of use, cost of operation based upon power cost, and minimum use of critical materials. If there is an existing water supply under the jurisdiction of the Department of the Army or other Government agency, an investigation will be made to determine its capacity and condition and the possible arrangements that might be made for its use with or without enlargement.

2-02. EXISTING SUPPLIES. Investigations of existing sources of supplies will include the following:

Source.

Reliability of supply.

Quantity developed.

Ultimate quantity available.

Excess supply available not already allocated.

Type of treatment.

Rates in g. p. m. at which supply is available.

Cost per 1,000 gallons.

Distance from site to existing supply.

Variation in pressure at point of diversion from existing system.

Ground elevation at point of diversion and at point of use.

Existence of contaminating influences.

Quality of water.

2-03. WELL SUPPLIES. If existing supplies cannot be utilized economically, an investigation to determine the availability and economy of well supplies should cover the following:

Reports on ground-water resources from the State Board of Health, the State Geologist, and/or the U. S. Geological Survey.

Reports on rainfall (distribution, maximum and minimum intensity).

Reports from operating water companies securing supplies from the formations.

Records of available well logs, draw-down data, total pumpage from area, both seasonal and long term, and variations in elevation of ground-water table.

Records of permeability of the acquifer and velocity of the ground-water flow (laminar or turbulent).

Records of physical, chemical, and bacteriological analyses.

Existence of contaminating influences.

Necessity for treatment, such as iron removal, softening, corrosion control, taste, and odor.

Spacing required between wells to prevent mutual interference.

Legal clearance if required by proximity to well fields of others.

2-04. SURFACE SUPPLIES. In the absence of existing supplies and the nonavailability of adequate and economical well supplies, investigation to determine the availability and economy of surface supply will include the following:

Topographic maps showing total tributary drainage areas of stream or reservoir.

Reports on rainfall (distribution, maximum and minimum intensity).

Reports on runoff and stream flow (variations in stream flow).

Survey of contaminating influences including quantity, location, and degree of treatment of sewage entering stream and quantity, location, and nature of industrial wastes entering stream.

Records of physical, chemical, and bacteriological analyses of proposed supply.

Feasibility of obtaining supply without construction of a reservoir.

Location of available reservoir sites and geological data relating to underlying formations that may affect foundation conditions or ability to hold water.

Location and probable cost of reservoir, pumping station, supply line, and treatment plant.

Plans of others to develop reservoirs on the same watershed, and water rights of downstream users.

2-05. ANALYSIS OF SUPPLY. Where new water sources are being

developed, physical, chemical, and bacteriological analyses will be secured to determine whether treatment is required to make the water safe and potable, or satisfactory for cooling purposes, laundries, and boiler use. It is imperative that the chemical properties of the water be known in the early stages of the project so that central purchase and selection of proper type of water-treating equipment may be accomplished without delaying the completion of the project.

2-06. WATER-SUPPLY WELLS.

a. Test Drilling. Prior to the construction of permanent water-supply wells, a careful investigation will be made of any and all wells in the vicinity. If there are no existing wells in the area, the topography and geology of the region will be studied and test wells driven. Rotary test drilling is rapid and economical for extensive explorations in unconsolidated materials.

b. Well Construction. Well construction will, in general, conform to the American Water Works Association Standard Specifications for Deep Wells. Gravel-wall-type wells will be constructed where the nature of the water-bearing formation indicates that this type of construction is desirable or necessary. When requested by state authorities, plans for proposed facilities may be furnished for information, but are not subject to review and approval by state agencies. Where well permits are required by the state in accordance with underground-water-resources conservation policies, full cooperation will be given to the state authorities regarding the withdrawal and use of equitable quantities of the underground-water supply.

c. Well Houses. Frame construction with timber derrick for handling well pump may be used, except where special fire hazards exist or in permanent posts where masonry fire-resistive houses will be provided. Where climatic conditions permit, well houses may be dispensed with and weatherproof motors, pumps, and control equipment installed.

d. Well Pumps. Commercially available pumps such as turbine, submersible, or other suitable types will be used. Pumps will not be purchased until the capacity and drawdown of wells are known and total head conditions determined.

e. Meters. A direct-reading meter will be installed in the discharge line from each well pump. Velocity-type meters may be used for this service.

f. Number of Wells. Not less than two wells will be provided except in the case of very small camps or when flowing artesian wells or springs are developed. A sufficient number of wells will be developed to yield the required daily demand for water in approximately 16 hours. In case two wells are completed, one of the wells will be equipped with a combination electric-motor gasoline-engine-driven pump unless there are two adequate and independent sources of electric power available. In addition to satisfying the above requirements, the aggregate capacity of well pumps equipped with gasoline-engine drive will equal at least 50 percent of the total well-pump capacity.

2-07. SURFACE-WATER PUMPING STATIONS.

a. Arrangement of Raw-Water Pumping Stations. The arrangement of intake structures and raw-water pumping stations will depend entirely upon the requirements of the specific situation. In general, a pumping-station arrangement adapted to the utilization of horizontal centrifugal pumps in a dry pit will provide for greater operating economy, although in certain instances, the use of vertical-type pumps taking suction direct from a receiving well may prove to be more economical. The use of automatic priming equipment in dry-pit installations may effect savings in construction cost.

b. Substructures. Substructures will usually be constructed of reinforced concrete.

c. Superstructures. Superstructures will be of low-cost fire-resistive construction for temporary camps and cantonments. Masonry fire-resistive construction, conforming to the type of existing structures, will be provided for permanent posts.

d. Pumping Equipment. In general, the size of the pumping units in the raw-water pumping station will be fixed by the size of the filter units and the total rated capacity of the filtration plant. A minimum of three motor-driven pumps will be installed with sufficient range of capacity to permit operation of the filtration plant at rated

capacity with the largest pumping unit out of service. In addition, a sufficient number of the pumps will be equipped with dual electric-motor gasoline-engine drives, or standby gasoline-engine-driven pumps capable of supplying 50 percent of the rated capacity of the filtration plant will be installed, except where a greater capacity is indicated or required.

e. Pumping-Station Control. Supervisory or remote control of motor-driven pumping units from the filtration plant is desirable if such control will eliminate the need of operators at the pumping station.

2-08. FILTRATION PLANTS. Filtration plants will usually be required for the treatment of domestic-water supplies obtained from surface sources and from ground-water supplies containing excessive quantities of iron and manganese. The principal treatment methods include screening, plain settling, coagulation, and sedimentation, filtration, disinfection, softening, and aeration. All water supplies will not require every type of treatment mentioned. Existing plants will be enlarged and utilized completely where practicable. Equipment and space for storage, measuring, or feeding chemicals will be arranged as compactly as possible, consistent with accessibility for operation and maintenance. Short solution lines are desirable; long lines will be avoided where possible. Convenience in handling materials is a prime consideration. The chemical-unloading point will be as near as practical to the place of storage, which, in turn, will be reasonably near the feeding equipment. The ready availability of supplies will be considered in determining space requirements for storage of chemicals. Bags will normally be stacked not more than 4 feet high. A 60- to 90-day supply is the usual bag-storage requirement.

a. Degree of Treatment. Partial treatment consisting of coagulation and sedimentation only may be required for process-water supplies. Complete treatment including filtration and sterilization will usually be required for drinking-water supplies taken from surface sources. Softening will usually be provided only for water required for laundry, hospital, and power-plant use and may be accomplished by the installation of industrial-type zeolite softeners at such structures. However, in case an excessively hard surface or underground supply is to be used, softening of the entire supply may be justified. Water-

treatment plants will, in general, be designed using design factors established in the American Society of Civil Engineers Manual of Engineering Practice No. 19 entitled "Water Treatment Plant Design," adopted 23 July 1939. Reference will also be made to the Manual of Water Quality and Treatment, published in 1950 by the American Water Works Association. When requested by state authorities, plans for proposed facilities may be furnished for information but are not subject to review and approval by state agencies.

b. Capacity. Filtration plants will have a normal rated capacity, based on 24-hour operation, equal to the required demand when operating at a filter rate of 2 gallons per square foot per minute. No spare filter units will be provided but plant piping will be designed to handle flow rates 50 percent in excess of the rated capacity. To secure operating flexibility, the required filter capacity will be secured by providing at least two filter units. The selection of site and arrangement of sedimentation basins and filter units will be such as to permit expansion at a minimum cost.

c. Type of Filtration-Plant Construction. Reinforced-concrete substructures with wood or low-cost-fire resistive superstructures will be used. Masonry superstructures conforming to existing construction should be used for permanent posts. The utilization of wood settling tanks or cut- and fill-type settling basins with paved sloping-side walls and tub-type filters is recommended where possible.

d. Elements of Plant. In general, filtration plants treating surface supplies should include the following:

(1) Chemical-feed equipment. Machines for the application of filter alum or other coagulant, lime, activated carbon, and chlorine (duplicate machines), will be required for all filtration plants.

(2) Chemical mixing and coagulation. Mixing will be done in baffled chambers. Mechanical mixing and flocculating equipment may be justified for plants having capacities greater than 1.0 m.g.d.

(3) Settling basins. Cut- and fill-type settling basins with paved sloping-side walls or wood settling tanks should be used where possible. Mechanical sludge-removal equipment will not be installed. Arrangement of basins will be such as to permit bypassing of any single unit.

(4) Filters. The number and size of filter units will depend upon individual requirements for economical design and operation.

(5) Filtered water storage. Clear-well capacity in an amount to meet wash-water requirements and to permit satisfactory operation of pumps and filters should be provided. (See paragraph 4-07, STORAGE CAPACITY.)

(6) Laboratory. Each plant should be provided with a laboratory properly equipped to make routine control tests appropriate for the size and character of the plant. (See Appendix II).

2-09. HIGH SERVICE PUMPING.

a. Type of Structure. The pumps will be installed in a building conforming in general to the requirements set forth in paragraph 2-07, SURFACE-WATER PUMPING STATIONS.

b. Type of Pumps. Horizontal centrifugal pumps in a dry pit are usually best suited for high-service pumping. A minimum of three motor-driven pumps should be provided with sufficient range in capacity so that the average and maximum rates (maximum rate equals one-half the average daily rate plus the fire flow, or two and one-half times the average daily rate, whichever is the greater) can be delivered. A sufficient number of the pumps should be equipped with dual drives and gasoline engines or standby gasoline-engine-driven pumps should be installed, capable of supplying 50 percent of the required demand except where a greater capacity is indicated or required. The following units would generally provide the desired flexibility in pumping capacity for a plant serving, for example, a required demand of 3.0 m.g.d. where adequate elevated storage is provided:

Two - 3-m.g.d. motor-driven pumps.

One - 1-1/2-m. g. d. motor-driven pump.

One - 1-1/2-m. g. d. gasoline-engine-driven pump.

Note: 1-1/2-m. g. d. pump equipped with dual drive for operation with either a motor or gasoline engine may be substituted for the 1-1/2-m. g. d. motor-driven pump and 1-1/2-m. g. d. gasoline-engine-driven pump.

c. Suction and Discharge Piping. The design of suction and discharge piping for the pumps will provide for the maximum reliability of service. The layout will provide piping with fittings so connected and valved that the failure of any one pipe, valve, or fitting will not disable more than 50 percent of the pumping capacity at one time. Where economically feasible, two discharge mains should extend from the pumping station to the underground piping of the distribution system supplying the project, although long parallel mains between pumping station and the distribution system are not contemplated.

SECTION III - METHODS FOR SPECIAL WATER TREATMENT

3-01. GENERAL. In addition to the usual treatment that may be required for clarification, color reduction, bacteria removal, and sterilization to insure delivery of a safe and potable water, consideration must also be given to the necessity for special treatment to protect pipelines, water heaters, plumbing fixtures, and other equipment against scaling, corrosion, staining, and "red-water" difficulties. Owing to the widely varying conditions and the multiplicity of types of water, it is not possible to establish criteria to be followed in all cases of special water treatment. Treatment for the prevention of scaling and corrosion may not be entirely effective and in many cases, a decision as to the necessity for special treatment cannot be reached prior to actual operating experiences. In general, special treatment will be provided only in cases where a study of the water analysis and actual experience with the water definitely shows that severe corrosion of the water system will exist or that severe scaling of hot-water heaters, storage tanks, and other parts of the plumbing system will occur, thereby resulting in high cost for replacement and use of critical materials. Marginal cases will be deferred and treatment provided only after operating experience determines treatment to be necessary.

3-02. CHEMICAL ANALYSIS. After decision has been made concerning the source of water for a new project, arrangements will be made to secure a representative sample (approximately 1 gallon) and to have a complete chemical analysis made by a U.S. Geological Survey Laboratory. Where the USGS laboratory is not available, an analysis by a commercial laboratory sufficiently experienced in making complete water analyses will be satisfactory. The results of this analysis will be forwarded to the applicable design agency headquarters for information.

a. Form of Analysis. For purpose of comparison and standardization, all analyses should be reported in the following form:

Water Analysis

	p.p.m.
Total dissolved solids	
Total solids	
Calcium as Ca	
Magnesium as Mg	
Sodium and potassium as Na	
Sulfates as SO_4	
Chlorides as Cl	
Bicarbonates as HCO_3	
Carbonates as CO_3	
Nitrates as NO_3	
Alkalinity (methyl-orange) as $CaCO_3$	
(phenolphthalein) as $CaCO_3$	
Iron as Fe (dissolved)	
Iron as Fe (total)	
Silica as SiO_2	
Fluoride as F	
Manganese as Mn (dissolved)	
Manganese as Mn (total)	
Total hardness as $CaCO_3$	
Carbonate hardness as $CaCO_3$	
Noncarbonate hardness as $CaCO_3$	
Free carbon dioxide as CO_2	

Resistivity in ohms per cubic centimeter (ohm/cm^3) @ 25° C.	
pH value	

b. Information on Existing Supplies. When water is to be purchased from a city supply or other source already developed, it may be possible to secure a representative analysis immediately. However, if the available analysis is not complete, a separate analysis will be made as noted herein. A brief description of the source of water and any treatment that may have been given prior to delivery to the distribution system should be furnished with the analysis. If possible, supplementary data will be furnished with all analyses describing the effect of the water on water heaters and related equipment. Any

unusual scaling or corrosion difficulties at Army or Air Force installations will be covered in detail.

c. U.S. Geological Survey Laboratory. A representative 1-gallon water sample will be shipped in one or more clean glass containers, addressed to the Water Resources Laboratory, United States Geological Survey, Washington, D.C., or to the nearest field office, for analysis. The samples will be labeled with the name and location of the post or station, date of collection, and name of person submitting samples. To assist the U.S. Geological Survey Laboratory in making analyses and in order that their records may be complete, it is essential that samples be carefully taken and marked for identification and that certain information accompany the samples forwarded to the Laboratory. The authorities at the Laboratory have requested that in addition to a gallon sample, a smaller sample (4 to 8 ounces) will also be furnished to simplify the analytical work in the laboratory. Care will be taken to see that sample bottles are thoroughly cleaned and rinsed with the water being sampled. Bottles should be filled, with an airspace of approximately 1/2 inch in the neck of a 4-ounce bottle, 1 inch in an 8-ounce bottle, and 1-1/2 inches below the stopper in a gallon sample to allow for expansion. A gallon sample will expand about 25 cc., when the temperature changes from 39 to 95 degrees F. Too large an airspace may permit some change in the composition of the water. Samples, when collected from wells, will be representative of the water in the underground formation and not of that which has stood in contact with the well casing or pump. If possible, the well pump should be allowed to operate 10 minutes or longer before collecting the sample. When collecting a sample from a water-distribution system, water should be permitted to flow from the spigot for at least 5 minutes before collecting the sample. After samples are collected, each sample will be clearly marked for identification and the information called for below will be furnished. This information will be attached to the sample bottle or placed in the shipment with the water samples, properly identified with respect to the samples:

d. Information with Samples.

(1) Well-water samples.

(a) Ownership and location of well. Indicate

county, state, and distance and direction to nearest town.

(b) Date well was drilled.

(c) Depth and diameter of well and length of casing.

(d) Yield in gallons per minute. State whether quantity was measured or estimated.

(e) Distances of water level in well both when idle and when being pumped.

(f) Date and temperature of water when sample was collected.

(g) Appearance. State if clear and colorless when collected and if not, describe particularly the appearance of any suspended matter and note color. This information is necessary to determine the procedure for analysis of a sample that is turbid when received.

(2) Surface-supply samples.

(a) Describe source such as river, lake, spring, etc.

(b) Describe briefly any treatment given to water, mentioning the various chemicals used and average dosage in parts per million or grains per gallon prior to delivery to system.

(3) Distribution-system samples.

(a) If from a city system, state name of city and furnish information as listed under (1) or (2) above, as applicable.

(b) If from post-distribution system, state name of post and furnish information as listed under (1) or (2) above, as applicable.

3-03. **WATER SOFTENING.** The entire post supply will not be softened unless the total hardness exceeds 400 p.p.m., expressed as equivalent $CaCO_3$. However, when a treatment plant is constructed for the removal of turbidity or iron, the plant may also be designed to accomplish partial softening. Softening of a post water supply to a total hardness of less than 100 p.p.m. expressed as $CaCO_3$ is not required.

a. Water for Laundries. Water for laundries should be softened if the total hardness is 2.5 grains per gallon (43 p.p.m.) or more, expressed as equivalent $CaCO_3$. Installation of zeolite softeners for this treatment is recommended and the equipment for this treatment is covered by Corps of Engineers plans and specifications for laundry construction.

b. Boiler-Water Treatment. Water for power plants and heating plants may require softening by means of zeolite softeners, or other means of treatment depending upon local conditions.

c. Softeners for Messhalls. The installation of softeners for small messhalls, latrines, and bathhouses is not recommended. The installation of zeolite softeners may be justified for large central messhalls to protect equipment.

d. Water for Hospitals. Partial softening of water delivered to hospitals and hospital areas may be justified to protect expensive and critical equipment in case the hardness exceeds 300 p.p.m. However, before a decision is reached to soften all water delivered to the hospital area, consideration will be given to the use of small zeolite softeners to supply softened water only to operating rooms, dispensaries, and messhalls.

3-04. SCALE PREVENTION.

a. General. Many waters, when heated, cause excessive scale and clogging of hot-water heaters, piping, and storage tanks. This scaling usually occurs in waters containing a high percentage of calcium and magnesium bicarbonate. If permitted to accumulate, the scale causes cracked heaters, reduced efficiency of heating equipment,

and necessitates the replacement of piping. It has been found that scaling is usually encountered with waters containing calcium in excess of 50 p.p.m.

b. Treatment to Control Scale. The excessive deposition of scale in hot-water heaters and piping can be largely controlled by the addition of nontoxic chemical compounds. In the case of moderate corrosion with scale-forming conditions, experience indicates that a combined treatment with special phosphates and sodium silicate may be effective in protecting water heaters and piping. These chemicals, when applied in small amounts, may be expected to accomplish satisfactory results even though the water may contain as much as 300 p.p.m. of bicarbonate alkalinity. The chemicals may be easily applied to well or pump discharge lines by means of small electric-motor-driven chemical-feed pumps actuated by the starting equipment controlling the well or booster pumps. Chemical-feeding equipment should not be installed indiscriminately and should be limited to those projects using water that is definitely known to be scale-forming. The Office of the Chief of Engineers will assist in determining the procedure to be followed with respect to treatment for corrosion and scale-forming difficulties at any installation upon receipt of detailed information concerning the project and the type of water to be used.

3-05. IRON REMOVAL. Treatment for iron removal or the correction of "red-water" difficulties is usually necessary for water supplies obtained from wells or other sources having an iron content in excess of 0.5 p.p.m. If the iron is present in a soluble or ferrous state, it may become oxidized to the ferric state if the water is exposed to the air or if air is drawn into the water system. A red precipitate will then form; this will cause deposits in hot-water tanks, staining of plumbing fixtures, staining of laundry, and may cause objectionable tastes and promote the growth of iron bacteria in water mains with clogging and reduction of carrying capacity.

a. Treatment with Sodium Hexametaphosphate. Operating experience indicates that for water containing not more than 3.0 p.p.m. of iron, the iron may be stabilized and kept in solution by feeding sodium hexametaphosphate. For maximum effectiveness, it is necessary to introduce the chemical into the water before it has become exposed to the air, and in the case of the treatment of well waters, the hexametaphosphate is usually introduced into the suction of the well pump.

The customary dosage varies with the amount of iron present and the minimum treatment is usually at the rate of 1.0 p.p.m. of sodium hexametaphosphate for each part per million of iron in the water.

b. Conventional Methods of Iron Removal. When the iron content exceeds 3.0 p.p.m., a conventional iron-removal plant including aeration, lime treatment, sedimentation, contact beds, or filtration may be necessary. This treatment is more desirable from the standpoint of the use of critical materials than the use of chlorine for the oxidation of iron followed by contact beds or treatment by filtering through beds of synthetic resins. In some cases, well-water supplies having a high iron content when the wells are first completed, show a reduction under continuous pumping thereby obviating the necessity for iron removal. It is, therefore, important that the true quality of well supplies be ascertained before planning treatment works.

3-06. CORROSION CONTROL. Water is a universal solvent and since iron is slightly soluble in water, it is possible under certain conditions to have serious corrosion of the waterlines in the water-distribution system as well as in house plumbing, hot-water heaters, and storage tanks. Corrosion difficulties are usually associated with waters having a low alkalinity, low pH value, high free CO_2, and low total mineral content. The action of corrosive water on ferrous materials will cause "red-water" difficulties, reduction in carrying capacity of mains, and the rapid deterioration of hot-water storage tanks. These become perforated in a short time, necessitating replacement with the use of critical materials. Where a study of water analysis and local conditions show that rapid corrosion of hot-water tanks may occur, the policy of using cement-lined tanks for those projects is established. Accelerated tests have been conducted by the Office of the Chief of Engineers using cement-lined tanks, and it is known that these tanks are satisfactory for use with fluctuating temperatures and pressures, and that the cement lining will definitely prevent the corrosion of the interior. The lower the pH value of the water, the more rapid will be the rate of corrosion. Water with a pH value of 9.0 will dissolve only traces of iron whereas water with a pH value of 6.0 will dissolve appreciable quantities of iron.

a. Methods of Corrosion Control. Owing to the wide variation in the chemical properties of the water, it is difficult to establish

the exact methods and types of treatment for the prevention of corrosion. For that reason, treatment for the control of corrosion should be installed initially only at those locations where a study of the water analysis or experience with the water show conclusively that it will be definitely corrosive. Generally, a water saturated with calcium carbonate will not be corrosive. Certain waters not saturated with calcium carbonate may also not be corrosive if dissolved oxygen is absent. Corrosion may be reduced by adjusting the chemical balance of the water to a condition approaching calcium carbonate saturation. This may be secured by the addition of lime, soda ash, or caustic soda. Lime is most effective when the calcium content of the water is less than 25 p. p. m. Since hydroxide alkalinity does not contribute to the saturation of the water with respect to calcium carbonate, there must be present sufficient CO_2 and bicarbonate alkalinity to convert only added lime to calcium carbonate. Therefore, if hydrated lime ($Ca(OH)_2$) is used, the dosage in parts per million of pure chemical should not exceed the sum of 1.68 times the parts per million of CO_2, plus 0.74 times the p. p. m. of bicarbonate alkalinity, expressed as $CaCO_3$. Any lime added in excess of these quantities has the effect of adding lime only. If lime sulphate is present, it may be converted to calcium carbonate by the addition of soda ash, Na_2CO_3, which will assist in building up the calcium carbonate concentration. Caustic soda is of limited value in correcting corrosion owing to the fact that it raises the pH value and alkalinity only and does not add to the concentration of calcium carbonate.

b. Treatment of Surface Waters. If alum is used for the coagulation of surface water prior to filtration, the filtered water may be corrosive unless it is treated for pH correction. This may be accomplished either by feeding lime with the alum or by applying lime to the filter effluent. Treatment of the filter effluent will be necessary when coagulation at low pH is required for the removal of color and in such case, the chemical may be applied to the clear well at a point that will permit thorough mixing before the water is pumped into the distribution system.

c. Treatment of Well Waters. Where treatment of well waters is required, it may be necessary to collect the water from all wells in a central ground reservoir to permit the application of the chemical prior to delivery to the distribution system. Where the

calcium content is low, lime treatment will be effective for corrosive control. In some instances, the calcium content and pH value may be such that the application of soda ash or sodium silicate will be satisfactory for corrosion control.

SECTION IV - WATER-STORAGE TANK

4-01. GENERAL. The judicious location of elevated or high-level storage tanks with respect to the distribution system and source of supply will enable the use of minimum pipe sizes in the distribution system. In general, storage tanks should be located near centers of water demand and so situated as to equalize pressures during periods of peak demand.

4-02. STORAGE CAPACITY.

a. Camps and Cantonments. Total storage capacity including elevated and ground storage, should be provided in an amount not less than 50 percent of the total daily consumption or in an amount sufficient to supply the fire requirements, whichever is greater. This storage may be reduced in cases where the project is supplied from an existing supply with adequate storage through relatively short supply lines or where the supply is obtained from wells located at strategic points on the distribution system, all of which are equipped with standby power facilities. If wells are located within the distribution system area and are all equipped with standby gasoline-engine-drive, storage in an amount of not less than 25 percent of the total daily demand should be provided. However, this amount of storage plus the output of the well pumps during the fire period must equal at least the total fire demand during the fire period. If only 50 percent of the total well capacity is provided with standby gasoline-engine power, storage in the amount of 50 percent of the total daily demand should be provided. The capacity of the clear well at filtration plants may be considered in reducing the storage requirements. When water is purchased and no storage is provided, the distribution system will be designed to deliver 1/2 the rate for average domestic consumption in addition to the required fire flows.

b. Storage Projects. Depots, ports, and similar projects will require 500, 000 or 1, 000, 000 gallons ground storage depending upon the size of the project. A minimum of 50, 000 gallons in elevated storage should be provided to supply domestic requirements, if elevated storage is necessary.

c. Plant Projects. The amount of storage required for plant projects will be based on the industrial, domestic, and fire protection requirements. Each project must be considered on the basis of specific needs.

4-03. HIGH-LEVEL STORAGE. High-level storage can be most economically provided by constructing ground-storage reservoirs on high ground. In the absence of suitable terrain for high-level ground reservoirs, not less than 50 percent of the total storage should be provided in elevated tanks, except where this type of storage is not desirable for military reasons. For projects with a population of ten thousand or less, consideration may be given to providing all storage in elevated tanks.

4-04. LOCATION OF ELEVATED TANKS. Elevated tanks should be located near load centers to equalize pressures over the distribution. In large areas, such as division areas, the total storage should be provided in at least two tanks located in separate areas.

4-05. STATIC PRESSURE. Reservoirs should be so located or heights of elevated tanks so established, as to provide a static pressure of not less than 40 pounds per square inch at the highest ground elevation in the post area. Where variations in topography will result in a pressure exceeding 100 pounds per square inch in small low areas, pressure-reducing valves should be installed in the mains serving these areas. If a substantial portion of the system will be subjected to high pressures when maintaining a minimum of 40 pounds per square inch in the high areas, consideration will be given to dividing the water-distribution system into a two-level system, each level being provided with its own water-storage facilities. If a two-level system is adopted, booster pumps will be required to deliver water from the low-level system to the high-level system.

4-06. STORAGE TANKS. The following types of tanks may be used for water storage:

a. Ground Storage.

Concrete-lined cut- and fill-reservoir.

Wood-stave tank.

Reinforced-concrete tank.

Steel tank.

b. Elevated Storage.

Wood-stave tank on wood, concrete, or steel tower.

Reinforced-concrete tank on concrete tower.

Steel tank on steel tower.

4-07. TANK RISERS. Risers to elevated tanks will be large enough in diameter to prevent freezing.

4-08. TANK FOUNDATIONS. Foundations for elevated tanks will be in accordance with the requirements of, and will be checked and approved by the tank manufacturer.

4-09. RESERVOIR COVERS. Tanks and reservoirs will be covered to prevent possible contamination and algae growths.

4-10. ALTITUDE VALVES. Single-acting altitude valves will be installed where necessary to prevent overflow from elevated tanks or standpipes. Altitude valves, when used, will be installed in concrete pits.

4-11. AUTOMATIC CONTROL. Automatic control of pumping equipment at wells or booster stations by control equipment actuated by water levels in storage tanks is desirable to reduce operating-labor costs. Automatic controls will not be used where pump operators are always in attendence.

SECTION V - DISTRIBUTION SYSTEM

5-01. GENERAL. The design of the distribution system will be as simple as possible and at the same time provide adequate service for maximum domestic requirements and fire protection. The judicious location of elevated storage tanks and interconnected and looped feeder mains will enable the use of minimum pipe sizes.

5-02. DUAL SYSTEMS. In general, dual-water system, such as a domestic supply from a safe source and a contaminated or questionable supply for irrigation, sprinkling, or fire-protection uses, or process or cooling purposes, will not be permitted, except where there are some very special reasons for the necessity of such a dual system. Where these reasons exist, they will be reported and prior approval will be obtained from the Office of the Chief of Engineers and the Surgeon General. If approval is given, the pipelines used for the two services will, if possible, be of different materials,and each service will be clearly and definitely identified.

5-03. CROSS CONNECTIONS. If two independent safe-water supplies are to be interconnected, approval of the producers will be obtained. There must be no physical connection between the water-supply and the sanitary-sewerage systems, including sanitary and storm-sewer manholes, sewage pumps, etc. An interconnection between a water supply of good quality and one that is unsafe is not permitted.

5-04. DISTRIBUTION MAINS.

a. Sizes of Mains. Sizes of mains are dependent upon fire demand, special requirements, and domestic demand. All items should be considered and the size of mains determined from the greatest flow to be met, due consideration being given to residual pressures required for each demand. The minimum size of mains serving fire hydrants will be 6 inches.

b. Domestic Requirements. For domestic supply, the lines will be designed for a peak flow of two and one-half times the daily average (domestic) requirements, with residual pressure of not less than 30 pounds per square inch. For plant projects, the total

daily consumption will take into consideration the total number of employees per shift, number of shifts, and whether or not showers and laundering of workers' garments are compulsory on the premises.

c. Fire Demands. Distribution mains will be designed to deliver the necessary fire-flow requirements plus 50 percent of the average domestic requirements with a residual pressure of 10 pounds per square inch in the vicinity of the fire. A residual pressure of 35 pounds per square inch will be required in warehouse areas, if automatic sprinkler systems are used. Deluge and other special sprinkler systems may require higher pressures.

d. Friction Losses. In computing losses for distribution mains, use C = 120 in the Williams and Hazen formula. In computing friction losses for supply mains, consideration may be given to higher coefficients that may be applicable to the type of pipe used.

e. Hydrant Branches. Fire-hydrant branches (from main to hydrant) should be not less than 6 inches in diameter and as short in length as possible and preferably not longer than 50 feet, with a maximum limit of 300 feet.

5-05. PRESSURES IN DISTRIBUTION SYSTEMS.

a. General. Water-distribution systems will be so designed that normal pressures in distribution mains and building service lines will be in the range of approximately 40 pounds per square inch to 75 p. s. i. at ground elevation. However, the systems will not be broken into a two-level system unless the pressures due to variation in topography exceed 100 p. s. i. in low areas. In small low areas where pressures approach or exceed 100 p. s. i., pressure-reducing valves on feeder mains to those areas may be installed to maintain pressures between 40 and 75 p. s. i., without constructing separate storage facilities for the low areas. Minimum pressures at ground elevation in high areas will be 30 p. s. i. under peak domestic-flow conditions.

b. Multiple Levels. Where two-level systems are required, it is desirable to establish the point of separation so that the pressures in each system will approach the optimum range of 40 to 75 p. s. i. A three-level system will not be used unless pressure in a large area of

the two-level system approaches or exceeds 100 p. s. i.

c. Pressure-Reducing Valves. Pressure-reducing valves will ordinarily not be required on service lines where the distribution system is laid out in accordance with present criteria in this manual as detailed above. However, in small areas where the pressure may exceed 100 p. s. i., and where it is impracticable either to develop a two-level system or to install pressure-reducing valves in the feeder mains to the area, pressure-reducing valves will be installed on building service lines in the area. Pressure-reducing valves will be installed to protect certain plumbing or heating units or other equipment where these units are inadequate to withstand pressures up to 100 p. s. i. These valves may be installed either on the building service line or on individual lines to the various units, whichever arrangement is more economical or feasible.

d. Pressure-Relief Valves. In a system with 100-p. s. i. fire pumps, pressures will be allowed up to 120 p. s. i. for short periods during testing or operation of these pumps. However, if the characteristic pump curve indicates that shutoff pressure exceeds 120 p. s. i., pressure-relief valves will be installed in the pumping station and set at approximately 110 p. s. i.

5-06. DIRECT-PRESSURE SYSTEMS. Direct-pressure distribution systems should be considered only where the military use or other special requirements will not permit the utilization of elevated storage tanks. For such systems, a sufficient number of gasoline-engine-driven pumping units will be installed to supply the peak requirements. For most systems of this type, the installation of three electric-motor-driven pumps capable of supplying peak domestic demand when operating simultaneously, and one or more units equipped with dual drives and gasoline engines or separate gasoline-engine-driven pumps capable of supplying the fire demand (fire flow plus 50 percent of the average domestic demand), will provide the necessary flexibility of operation.

5-07. BALANCED PRESSURE SYSTEMS. High-level storage either in surface reservoirs located on high ground or in elevated tanks should be utilized wherever conditions will permit. This will enable the use of minimum pipe sizes in the distribution system.

5-08. LOCATION OF MAINS. Mains should be located along streets in order to provide short hydrant branches and service connections. Looped grid systems are desirable for distribution systems and dead ends should be eliminated on mains wherever possible; if dead ends in mains are unavoidable, provision will be made for blowing off the line by means of a valve or hydrant. Mains will not be laid horizontally closer than 10 feet from a sewer except where bottom of water pipe will be at least 12 inches above top of sewer pipe, in which case the water pipe will not be laid horizontally closer than 6 feet from the sewer. Where waterlines cross under gravity-flow sewer lines, the sewer pipe for a distance of at least 10 feet each side of the crossing, will be fully encased in concrete or will be made of pressure pipe with no joint located within 3 feet horizontally of the crossing. Waterlines will in all cases cross above sewage force mains or inverted siphons and will not be less than 2 feet above the sewer main. Joints in the sewer main horizontally closer than 3 feet from the crossing will be encased in concrete.

5-09. LOCATION OF VALVES. Valves will be installed at intervals of approximately 5,000 feet in long supply lines and at intervals of from 1,200 to 1,500 feet in main distribution loops or feeders and on all primary branches connected to these lines. Valves will also be installed at selected points throughout the distribution system to provide control over reasonably sized areas. At intersections where several valves are required, the number of valves will ordinarily be one less than the number of radiating lines. Valves are required on branches serving wet-barrel-type hydrants unless the hydrants are furnished with automatic-breakoff check valves. Valves are not required on branches serving dry-barrel-type hydrants except (1) where hydrants are installed in main distribution feeders so laid out that repairs to a hydrant would necessitate closing off a considerable area from water service and fire protection, or (2) where hydrants are particularly subject to damage by unusual traffic hazards and cannot be protected against damage by means of post barrier or other means using noncritical materials.

5-10. FIRE HYDRANTS.

a. Hydrant Spacing. For housing areas, hydrants will generally be spaced approximately 400 feet apart and so located that any part of each building can be reached from one hydrant with a

maximum length of 300 feet of hose. Where single or duplex family units are located on dead-end streets, the distance to a second hydrant may be 500 feet to obviate the need for an excessive number of hydrants.

Hydrants will be spaced approximately 300 feet apart on both sides of warehouses. In open areas, one hydrant will be provided, strategically located, for each 100,000 square feet of open storage area. The distribution piping will be properly sized to permit delivery of the entire 4,000-g.p.m. fire flow from four hydrants in the immediate vicinity of a warehouse or shop.

For plants, the criteria for warehouse areas will generally be followed. In exceptional circumstances, a nonpotable supply may be used for fire-protection purposes.

b. Location of Hydrants. Hydrants will generally be located at least 50 feet from the nearest building and in no case will hydrants be located closer than 25 feet to a building except where building walls are blank firewalls. Safety for traffic and protection for fire hydrants make it desirable that hydrants be located not less than 6 feet from the edge of the paved roadway surface; and where practicable on primary roads, a greater distance should be allowed. Hydrants will be so located that connection with the hydrant can be made by the pumper, using a single length of 10-foot suction hose. In order to meet this condition, it will be necessary for the pumper to be placed not more than 7 feet from the face of the suction connection on the hydrant to the pumper connection. If hydrants are located more than 7 feet from the edge of the paved roadway surface and if the shoulders are such that the pumper cannot be placed within 7 feet of the hydrant, consideration may be given to stabilizing or surfacing a portion of wide shoulders adjacent to hydrants to permit the connection to pumper with a single 10-foot length of suction hose.

In exceptional cases, where ditches or other conditions prohibit locations meeting the above requirements, hydrants may be so located as to permit connection to the pumper, using two lengths of suction hose (a distance not to exceed 16 feet from the suction connection of the hydrant to the pumper connection). Isolated cases may

require special consideration to provide a location for the pumper to permit access to a hydrant.

Hydrants will not be located closer than 3 feet to any obstruction nor in front of entrance ways. Hydrants will be so set that the center of the lowest outlet is not less than 18 inches above the surrounding grade and the operating nut not more than 4 feet above the finished surrounding grade. The principal (pumper) discharge will face the nearest roadway.

5-11. AIR-RELEASE AND VACUUM VALVES. Air-release and vacuum valves will be installed at prominent peaks on long supply mains only. These valves will act automatically, permitting the escape of air from the pipeline while it is being filled and permitting the entrance of air while it is being emptied. Air valves will not generally be necessary in the grid distribution system of the project, as air accumulations will normally be released through service lines.

5-12. MINIMUM COVER OVER PIPES. Minimum cover over lines will be dependent on locality and depth of frost. Where frost does not govern, the minimum cover will be not less than 2 feet. Where lines pass under railroads, pipe will be encased in rigid conduit in accordance with the standard practice of the servicing railroad company or in accordance with the criteria contained in the Manual of Recommended Practice of the American Railway Engineering Association.

5-13. SERVICE CONNECTIONS. It is desirable and in the interests of economy that the service ends of buildings be located adjacent to streets and one water main installed along the street common to buildings on either side. Combination stop and waste cocks on underground service lines for draining building lines are not desirable because of potential contamination of the water supply. To prevent freezing, service lines to buildings should be installed below frostline and risers from frostline to floorlines of buildings adequately insulated. Water-service connections are required for servicing aircraft at airfields. These connections will normally be located adjacent to the parking apron at nondispersed stations or adjacent to the servicing apron at dispersed stations.

5-14 CLEANING OLD WATERLINES. Where old existing mains are to be used and these mains have become incrusted to such a degree that the flow has been materially reduced, it may be advisable and economical to clean them. This work should be accomplished by contract with well-established and experienced firms specializing in this work.

5-15. STERILIZATION OF WATER-SUPPLY SYSTEMS. In order that a safe supply of water can be assured, each unit of the system will be thoroughly sterilized before it is placed in operation. For methods of sterilization, see Appendix I.

5-16. PIPE MATERIALS FOR WATER MAINS AND SERVICE LINES. The following materials may be used for water pipelines:

Asbestos-cement pressure pipe.

Black wrought-iron pipe.

Cast iron pipe.

Cement-lined pipe.

Coated steel pipe.

Plastic pipe.

Reinforced-concrete pressure pipe.

5-17. LAYOUT MAPS. A layout map to suitable scale showing the distribution system for the project will be prepared in accordance with EM 1110-345-710 for Army construction and the existing statement of work for preparation of Air Force master plans.

SECTION VI - CHLORINATION OF WATER SUPPLIES

6-01. GENERAL. Equipment will be provided for chlorinating water supplies in accordance with the following:

a. Facilities for Maintaining Chlorine Residual. Facilities for maintaining a chlorine residual of not less than 0.4 p.p.m. in the active parts of the potable-water distribution system will be provided at all posts where the water-supply works are constructed and operated by the Army. This applies to well and surface supplies alike.

b. Facilities for Chlorination of Water. Facilities for the chlorination of water obtained from municipal or privately owned sources will be provided under the following conditions:

(1) Where the water has not been chlorinated by the Municipality or Utility Company prior to delivery to the post.

(2) Where sanitary, physical, or operating defects in the public water-supply system or other special hazards are known to exist or where water of a uniformly satisfactory quality, as evidenced by the result of bacteriological examinations, cannot be obtained without rechlorination.

c. Water Supplies. Water supplies to posts, depots, leased buildings, and similar facilities served directly and individually by a public water-supply distribution system will not be rechlorinated except where warranted in individual cases.

d. Chlorination. Where provision is made for the chlorination of water supplies, the point of chlorine application will be such as to provide not less than 30 minutes contact period. This requirement will be waived where additional reservoirs would be required to obtain this contact period. In general, the chlorine dosage will be sufficient to maintain a chlorine residual of not less than 0.4 p.p.m., in the active parts of the distribution system. This requirement is not to be considered mandatory in cases where:

(1) The presence of iron, manganese, or other chlorine-consuming compounds makes it impractical to maintain a chlorine residual of 0.4 p.p.m. in the active parts of the distribution system, provided these compounds are not of such character or in such an amount as to prevent effective initial chlorination.

(2) Where the water is stored for long periods in properly protected distribution reservoirs following chlorination. In these cases, the chlorine treatment will be sufficient to insure a potable-water supply as evidenced by satisfactory bacteriological samples. In the event the presence of mineral or organic compounds makes it impossible to produce a water of acceptable quality, treatment for the removal of such compounds will be required.

6-02. **USE OF AMMONIA.** If the use of chlorine alone results in objectionable tastes due to the presence of foreign matter or due to the chlorine itself, ammonia in conjunction with chlorine may be used. This use should be restricted to locations where the tastes are deemed to be very objectionable.

FOR THE CHIEF OF ENGINEERS:

W. M. Glasgow Jr.
WILLIAM M. GLASGOW, JR.
Colonel, Corps of Engineers
Executive

3 Appendixes
- I Sterilization of Water-Supply Systems.
- II Laboratory Furniture, Apparatus, and Supplies for Water-Filtration Plants.
- III Typical Design Analyses for Water-Supply Systems.

APPENDIX I - STERILIZATION OF WATER-SUPPLY SYSTEMS

Table of Contents

1. GENERAL. In the construction of water mains, wells, filters, storage tanks, and other units of a water-supply system, there is danger of contamination resulting from the introduction of harmful bacteria. Flushing the system to remove dirt, waste, and surface water that may be introduced during construction is not a sufficient safeguard. In order that a safe supply of water be assured, each unit of the system will be thoroughly sterilized before it is placed in operation.

2. MATERIALS. Sterilizing the various units of a water-supply system is readily accomplished by using chlorine. This agent is commercially available as liquid chlorine, liquid (sodium) hypochlorite, chlorinated lime (bleaching powder), or high-test (dry) calcium hypochlorite. Uniform concentrated solutions of chlorinated lime and calcium hypochlorite are easily prepared by mixing with water. This is often desired to facilitate the measurement and application of the material.

3. AVAILABLE CHLORINE. The sterilizing power of chlorine compounds is measured by the oxygen-releasing value of the chlorine, often referred to as the available chlorine. In liquid chlorine, the amount of available chlorine is 100 percent. In commercial hypochlorites, the amount of available chlorine is usually indicated on the container in percent by weight, but in general, corresponds to the following:

		Percent of Chlorine
Liquid chlorine	--	100
Calcium hypochlorite	--	70
Liquid hypochlorite	--	10
Chlorinated lime	--	35

4. STERILIZATION. The materials used for sterilizing various units of a water-supply system will be as follows:

Chlorine: Federal Specification BB-C-120.

Hypochlorite: Federal Specification O-C-114a (Int. Am-1) for calcium hypochlorite and chlorinated lime, or Federal Specification O-S-602b for sodium hypochlorite.

5. APPLICATION. The method used for applying the chlorine to the various parts of the water-supply system will depend upon local conditions. In general, the method selected will allow accurate measurement of the chlorine, insure a uniform mixture, and allow sufficient time of contact with the surfaces of the unit being sterilized. The form in which the chlorine is available will also be a factor in determining the method used.

a. Liquid Chlorine. Liquid chlorine, in equipment designed for this purpose, can be measured and applied either as a water solution or direct in gaseous form. The solution-feed method may be used if water pressures are available to operate the injector. Direct feed can be applied to open or gravity systems.

b. Liquid Hypochlorite. Liquid hypochlorite may be applied by means of measuring pumps, gravity-feed mechanisms, or directly into the suction of a water-supply or booster pump. There are several simple homemade devices which, in emergency, can be used for applying liquid hypochlorite solutions. In one method, the hypochlorite solution is mixed in a barrel or small storage tank and discharged through a hose. Various devices to provide a uniform rate of discharge are available, making use of float-operated valves, constant head, or variable orifice principle.

c. Dry Hypochlorite. Dry hypochlorite may be applied direct as a powder to the unit to be sterilized. Dry powder may be placed in supply mains as they are laid or in storage tanks and filters to be sterilized. When these units are filled with water, the hypochlorite will be taken in solution. This is a very crude method for applying

a sterilizing agent, but is sometimes necessary in the emergency of construction. Since uniform mixtures are difficult to obtain in this manner, it is recommended that excess dosages be applied to insure thorough sterilizing action.

6. DOSAGE CALCULATIONS.

a. Chlorine Required. The amount of chlorine required to thoroughly sterilize any unit of a water-supply system depends upon the thoroughness of mixing, the time of contact allowed, and the presence or absence of chlorine-consuming material such as dirt, mud, or algae. In general, if average conditions exist, the following minimum dosages are recommended:

	p.p.m.
Pipe system	50
Storage tanks	50
Filters	100
Wells	150

b. Capacity of Pipes. In estimating the amount of chlorine solution required for treatment, the volume of water contained in that portion of the supply main, distribution system, or other unit to be sterilized, is computed. The volume in cubic feet is readily converted to gallons by applying factor 1 cu. ft. - 7.5 gallons. In the following table the capacity in gallons for various size standard pipe is tabulated:

Pipe Size, Inside Diameter, Inches	Volume Capacity of 1,000-Foot Lengths, Gallons
4	653
6	1,468
8	2,611
10	4,080
12	5,875
14	7,997
16	10,443
20	16,322
24	23,504
30	36,722
36	52,880
42	71,970
48	94,030

c. Treating Solution. The treatment can best be accomplished by preparing a strong treating solution of known strength and calculating the amount of such solution required for the desired treatment. A 5-percent chloride solution, equivalent to a chlorine concentration of 50,000 p.p.m., is a convenient treating solution for such use. One gallon of treating solution having a chlorine concentration of 50,000 p.p.m., can be prepared with various strength commercial compounds, as follows:

	Percent Available Chlorine	Weight, Lbs.
Liquid chlorine	100	0.4165
Calcium hypochlorite	70	0.5950
Chlorinated lime	35	1.19
Liquid hypochlorite	10	4.165

NOTE: The amount of treating solution containing 50,000 p.p.m. available chlorine required to treat a given quantity of water to the required dosage, can be calculated as follows:

$$\frac{\text{Gallons of water to be treated} \times \text{p.p.m. chlorine dosage}}{50{,}000} = \text{Gallons treating solution required.}$$

7. METHODS. The unit to be sterilized will be thoroughly flushed with water until all entrained dirt and mud have been removed; then the sterilizing agent in an easily applied form will be admitted into the unit and allowed to stand for a sufficient contact period. In detail, the methods of application are as follows:

a. Supply Mains. Chlorine-treated water will be retained in the main long enough to destroy all nonspore-forming bacteria. This contact period will be at least 8 and preferably 24 hours and will produce no less than 10 p.p.m. at the extreme end of the line at the end of the period. The line will then be flushed with clean water until the residual chlorine is reduced to less than 1.0 p.p.m.

The most desirable method of sterilizing supply mains is either by introducing liquid chlorine into the main as described hereinbefore in paragraph 5: APPLICATION, or by introducing a hypochlorite solution into the suction or discharge of a pump using one of the arrangements previously described. If a pump or pressure feeder is not available and the mains are to be filled by pressure from an elevated storage tank, an injector may be used. If the latter method is employed, it will usually be necessary to measure or estimate the rate of flow by metering or by observing the time required to fill the

known volume of the main on a trial run. Tests will then be made to determine the injector suction required under the existing conditions to feed the desired quantities of chlorine. Another method involves the introduction of proper quantities of strong hypochlorite solution at various points in the completed pipeline by means of corporation cocks.

Where the above methods cannot be used, sterilization can be accomplished by introducing small measured quantities of hypochlorite into each length of pipe as the line is laid and then slowly filling the section to be treated with water. Uniform mixing of the hypochlorite with water is difficult by this method; therefore, high dosages and a long contact period will be used.

b. Distribution Systems. Distribution systems can be sterilized by methods similar to those described for treating supply mains. In construction of new systems, the chlorine or hypochlorite can be mixed with water in the elevated storage tank or in the storage reservoir from which that portion of the distribution system to be sterilized can be filled. Water from the elevated storage tank will flow by gravity into the system, and from storage reservoirs it can be pumped with booster pumps. Large distribution systems will be sterilized in sections, and the valves will be set to provide maximum circulation of the chlorine solution being introduced into the system. All valves and appurtenances will be operated while the solution is in the mains.

c. Wells. In sterilizing newly constructed wells, the following method can be used: The well and casing pipe will be thoroughly cleaned of all foreign substances. The total volume of water in the well will be estimated, and from this will be calculated the required amount of chlorine to secure the proper dosage strength. Hypochlorite, in solution form, can be introduced directly into the well by using gravity, pump, or drip feeders. Dry hypochlorite can be introduced and thoroughly mixed with the water in the well by using the bailer, if the drilling equipment is still available. After chlorine has been added and allowed to stand for a contact period of 24 hours, the well will be pumped to waste until the residual chlorine is less than 1.0 p.p.m., or until there is no objectionable odor of chlorine.

d. Filters. In the sterilization of newly constructed filter units, the following methods will apply: The filter unit will be thoroughly backwashed and the water level lowered to within 2 feet of the sand surface; the estimated quantity of hypochlorite will be applied to the water surface and the water level lowered to within 2 inches of the top of the sand and permitted to remain in contact for a period of at least 8 and preferably 24 hours. The filter will then be washed to waste until tests of the water show a residual chlorine not more than 1.0 p.p.m. The filter will then be placed in service. As an added precaution, dry hypochlorite can be introduced into the sandbed in layers as the sand is placed in the filter unit. This method will insure a more thorough mixing and better contact with the surface to be sterilized. Liquid chlorine or hypochlorite may also be introduced to the filter unit at the suction or discharge of the backwash or supply pump.

e. Reservoirs, Standpipes, and Elevated Storage Tanks. Chlorine will be introduced into the water as early as possible in the filling operation. This can be accomplished by adding the chlorine solution through the cleanout or inspection manhole in the lower course of the standpipe shell or in the base of the elevated-tank riser pipe. Where a liquid-chlorine and water mixture is used, a special tap can be provided in the manhole cover and the gas-water mixture pumped into the tank as the filling is started. If no bottom manhole is available, the chlorine powder or liquid-chlorine and water mixture can be scattered over the water surface in the partly filled tank, working from the roof manhole. The tank will stand full for a contact period of at least 8 and preferably 24 hours after which the tank will be thoroughly flushed with clean water until the residual chlorine is reduced to less than 1.0 p.p.m. In very large reservoirs and storage tanks, the surface of the walls, floors, and other parts that come in contact with stored water may be thoroughly sterilized by washing or spraying with a strong solution of hypochlorite. The hypochlorite solution used will contain at least 300 p.p.m. of available chlorine and will be applied with a brush or pressure spray. A period of from 2 to 4 hours will elapse after application before the reservoir is flushed and placed in service.

8. TESTS.

a. Residual-Chlorine Test. Residual chlorine will be determined by any of the methods described in the latest edition of either Standard Methods for the Analysis of Water, Sewage and Industrial Wastes published by the American Public Health Association, and the American Water Works Association or Laboratory Manual for Chemical and Bacteriological Analysis of Water and Sewage by Eldridge, Theroux, and Mallman.

b. Bacterial Test. After any given unit or portion of the water-supply system has been sterilized and the system has been thoroughly flushed with fresh water until the chlorine has been removed, samples of the water from several points in the system will be taken in properly sterilized containers and will be subjected to bacterial examination. If the supply is known to be of good quality and repeated tests of the samples show the presence of coliform organisms, the sterilizing will be repeated or continued until tests indicate the absence of pollution. The bacterial examination will be completed before any unit or portion of the system is placed in operation. Samples may be submitted to local State Boards of Health or to commercial testing laboratories if complete bacterial-testing facilities are not available.

APPENDIX II - LABORATORY FURNITURE, APPARATUS, AND SUPPLIES FOR WATER-FILTRATION PLANTS

Table of Contents

1. GENERAL. The following Schedule of Laboratory Furniture, Apparatus, and Supplies has been prepared for the various types of Water-Filtration Plants, as follows:

a. Class A Plants. Filtration plants serving a population of over 10,000 or treating surface water taken from a polluted source where complete control is required for the operation of the plant. The laboratory equipment provided will permit routine chemical and bacteriological analyses, as well as microscopic examinations.

b. Class B Plants. Filtration plants taking water from a slightly polluted source or from wells where softening or iron removal is required. The laboratory equipment provided will permit routine chemical control tests, bacteriological tests for coliform organisms, and total plate counts.

c. Class C Plants. Plants where chlorination only is provided to insure the bacteriological quality of the supply. The laboratory equipment will permit routine residual chlorine, pH, and alkalinity determinations only. The list of Laboratory Furniture and Apparatus is considered to be the minimum required. The equipment listed is complete in itself with all necessary details and accessories.

2. LABORATORY FURNITURE. The following list of laboratory furniture includes those items required in Class A and B plants. It is intended that this equipment will meet the minimum requirements for laboratory furniture. However, discretion should be exercised in selecting furniture that will fit the space requirements in the laboratory and harmonize with other facilities. It is recommended that the several units be purchased ready-made, as this type is preferable to built-in furniture. The equipment listed is complete in itself with all necessary details and accessories and the items listed are standard with at least three manufacturers. The tops of the table and the benches are of materials specially treated to resist the action of the chemicals. The furniture required is as follows:

Item 1. One Laboratory Table of oak, approximately 6'-0" long, 32 in. deep and 36 in. high. Table fitted with a maple bottle rack with acid-resisting back; rack approximately 60 in. x 8 in. x 18 in. Sink with back at end of table 14 in. x 18 in. x 12 in. mounted on tubular stand of 1-1/4 in. selected soapstone. Sink will have 2 in. lead "p" trap for connection to plumbing. Pegboard over sink, 14 in. x 19-1/2 in. fitted with 16 pegs. Tabletop fitted with a lead-lined (4 lbs. per square foot) trough, approximately 66 in. x 4 in. approximately 6 in. at deep end, properly pitched to drain. All joints will be burned with pure lead; soldering is not permitted. Cabinet supporting frame will be mortised and tenoned, glued, and reinforced with bolts. Drawers will be dovetailed; doors will be built up, and shall have suitable pulls, catches, and hinges. The cabinet will be equipped with two long drawers at top, four intermediate drawers, and two cupboards. Cupboards will be fitted with two adjustable removable shelves. Top shall be of shellstone or approved acid-resisting material. Equipment will have two compression hose bibs over sink for hot and cold water; three straight-way water cocks with hose connection over trough; and 1/2 in. pipe conduit with two duplex receptacles with "T" slots, mounted in cast-metal conduit fittings. Connections will be made to floor outlets. All service lines will be carried to floor with shutoff for each line. Finish for all exposed steel and service piping shall be acid- and alkali-resisting enamel.

Item 2. One Balance Shelf, 3 ft. long x 2 ft. wide; oak construction, except for 1-5/8 in. -thick birch, black carbonized top; equipped with drawer 21 in. wide, 15 in. deep, 3-3/4 in. high.

Item 3. One Supply Case of oak, 48 in. wide, 15 in. deep, 80 in. high, upper section glazed 44 in. wide, 60 in.

high with three adjustable shelves; cupboard shelves; cupboard section 44 in. wide, 12 in. deep, 13 in. high.

Item 4. One Lower Section Cupboard Unit 37-5/8 in. long x 24 in. wide x 36 in. high containing 1 double cupboard 34 in. wide x 28-1/4 in. high x 20-5/8 in. deep, with 1 stone sink 14-1/4 in. long x 10 in. wide x 8 in. deep with 1 set of drain fittings, 1 cold-water pantry cock and 1 double electric receptacle for 110-v., a. c., tabletop to be scored to drain to sink. All furniture shall be oak construction, natural finish throughout except tabletops which are to be 1-5/8 in. birch black carbonized.

Item 5. Laboratories for Class C Plants. The furniture to be provided consists of a worktable at least 48 in. long x 36 in. wide and 30 in. high, together with a wall cabinet fitted with doors. The cabinet will be of adequate size to house equipment and chemicals required for a Class C Laboratory. These items need not be of special laboratory construction, as kitchen-type or built-in-place furniture will suffice. A laboratory sink should be provided convenient to the worktable.

NOTE: Equipment of dimensions differing no more than 5 percent from those indicated will be acceptable. For standards of acceptable quality, refer to the following:

Laboratory Equipment, General Catalog No. 25, E. H. Sheldon & Co., Muskegon, Michigan.

Kewaunee Book of Wood Laboratory Furniture, Kewaunee Mfg. Co., Adrian, Michigan.

Laboratory Equipment, Catalog No. 212, Hamilton Mfg. Co., Two Rivers, Wisconsin.

3. LABORATORY APPARATUS. The following list of laboratory apparatus includes those items required in Class A, B, and C plants:

Laboratory Apparatus

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E.H. Sargent Co.	Fisher Scientific Co.
1	1		Balance, analytical, student model, chain type, w/ rubberized cloth cover.	2027	S-3965B	1-990A
1	1		Set Balance Weights, 1 gm. to 100 gm.	8119B	S-3991	2-224-5
1	1	1	Harvard Trip Scale Balance	3470	S-3215	2-035
1	1	1	Set Balance Weights 1 to 500 grams.	9125C	S-4285	2-301
1	1		37° C. Electric Incubator.		S-43505	11-689
1	1		Small Refrigerator.			
1	1	1	Two Burner Hotplate Gas.	16685	S-41475	4-220
1a	1a	1a	Hotplate Electric, 12" x 18" 3-heat.	16650	S-41125	11-500
1	1		Sterilizer oven, gas.	48242-A	S-76285	14-493
1a	1a		Sterilizer oven, electric, 3-heat	48210A	S-76265	14-490
1	1		Pressure sterilizer, 11" x 24", gas.	44120	S-76025-A	1-797-1
1			Electric muffle furnace, Hoskins type FD.	13675-A	S-36855 Size #202	10-511A Size # 202
1a	1a		Pressure sterilizer, electric, 11" x 24".	44122	S-76005	1-801-1A
1			Rheostat for furnace, muffle.	13678A	S-36875	10-513A
1	1		Jackson Turbidimeter	29105	S-83705	15-380

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E.H. Sargent Co.	Fisher Scientific Co.
1	1		Water still - Capacity 1 gal. per hour, gas heated.	12760	S-27465	9-022
1a	1a		Water still - Capacity 1 gal. per hour, electric heated.	12750	S-27415	9-018
12	12	6	Wide-mouth bottles, glass stoppered, 30-32 ounces.	10450	S-8395	2-910
18	18		Wide-mouth bottles, glass stoppered, 125 ml.	10450	S-8395	2-910
6			Dropping bottles, 30 ml.	10580	S-8785	3-000
6	6	3	Dropping bottles, 60 ml.	10580	S-8785	3-000
2	2	2	Wash bottles, 1,000 ml.	10710	S-9365	3-395
2	2		Pyrex bottles for distilled water, 2-1/2 gallons.	10480	S-8475	
4	2	2	Cylinders, double graduated, 100 ml.	16125	S-24695	8-554
2	1		Cylinders, double graduated, 500 ml.	16125	S-24695	8-554
2	1		Cylinders, double graduated, 1,000 ml.	16125	S-24695	8-554
1	1		Volumetric flasks, vial mouth, and stoppers, 50 ml.	16226	S-34845	10-204
2	1		Volumetric flasks, vial mouth, and stoppers, 100 ml.	16226	S-34845	10-204
2	1		Volumetric flasks, vial mouth, and stoppers, 250 ml.	16226	S-34845	10-204
2			Volumetric flasks, vial mouth, and stoppers, 500 ml.	16226	S-34845	10-204

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
1	1		Volumetric flasks, vial mouth, and stoppers, 1,000 ml.	16226	S-34845	10-204
24	24	6	Erlenmeyer flasks, pyrex, 250 ml.	14905	S-34105	10-040
6	6	4	Erlenmeyer flasks, pyrex, 500 ml.	14905	S-34105	10-040
2	2		Erlenmeyer flasks, pyrex, 1,000 ml.	14905	S-34105	10-040
4	2		Beakers, pyrex, 50 ml.	14265	S-4675	2-540
4	2		Beakers, pyrex, 150 ml.	14265	S-4675	2-540
12	6	4	Beakers, pyrex, 250 ml.	14265	S-4675	2-540
4	2		Beakers, pyrex, 400 ml.	14265	S-4675	2-540
6	2		Beakers, pyrex, 600 ml.	14265	S-4675	2-540
12	4	2	Beaker covers, 3-1/2 inches.	15850	S-83605	2-610
1			Filtering flask, 500 ml.	14985	S-34365	10-180
2			Filtering crucibles, Alundum, RA360, 24 ml.	10065-A	S-24375	8-230
2			Rubber crucible, holder.	18110	S-24475	8-285
2	2		Funnels, 100 m.m. diam.	15070	S-35305	10-320
4	2		Funnels, 65 m.m. diam.	15070	S-35305	10-320
2	2	2	Funnels, long stem, 100 m.m. diam.	15070	S-35315	10-325
12	12		Nessler tubes, 100 ml. marked at 50 ml.	29060-C	S-21035	7-057
4	4	2	Burettes, graduated in 0.1 ml., 50 ml.	15926-C	S-10635	3-699

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
2	2		Burettes, graduated in 0.1 ml., 25 ml.	15926-B	S-10635	3-699
4	4	1	Pipettes, Volumetric, exax blue line, 1 ml.	16355	S-69515	13-649
4	4		Pipettes, Volumetric, exax blue line, 5 ml.	16355	S-69515	13-649
4	4		Pipettes, Volumetric, exax blue line, 10 ml.	16355	S-69515	13-649
3	2	1	Pipettes, Volumetric, exax blue line, 25 ml.	16355	S-69515	13-649
3	2	1	Pipettes, Volumetric, exax blue line, 50 ml.	16355	S-69515	13-649
1	1	1	Thermometer, Centrigrade, -5° to 250°.	19240	S-80005	14-985
1	1		Watch glasses, counter poised, (pair) 2-1/2 in. diam.	2250	S-3785	2-195
2	2	2	Absorption tube, to hold soda lime.	14755-A	S-28815	9-215
1			Desiccator, 250 m.m. diam.	14560	S-25505	8-595
6	4	2	Evaporating dishes, porcelain 75 m.m.	18575	S-25505	8-690
4	2		Evaporating dishes, porcelain 90 m.m.	18575	S-25505	8-690
1	1		Pipette Stand.	19120	S-78905	14-745
1	1		Burette support, medium.	19080	S-78335	14-675
1	1		Burette clamp, steel.	12116	S-19105	5-781

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
1	1		Gas burner, mecker or fisher.	11105	S-12195/6	3-900/2
2	2	1	Gas burner, Bunsen, Tirrill type.	11027	S-12265/85	3-962
2	2	1	Stone jars for waste, 2 gallons.		S-43945	11-845
4	2		Pinchcocks, Mohr, 2-1/2 inches.	12186	S-19495	5-855
2	2		Clamps, test tube.	12155	S-19555	5-841
1			Spoon, horn, 150 m.m. long.	18780	S-75175	14-425
1	1		Spatula, stainless steel, 4 in. blade.	18755	S-75245	14-365
1			Filter Pump Aspirator.		S-33575-A	9-965-B
2	1	1	File, triangular, 6 inches.	88325	S-32235	15-223-10
1	1	1	Funnel support, hardwood.	19035	S-78815	14-740
1	1	1	Iron ring stand; 3 rings, 3", 4", 5".	19070	S-78305	14-670
1	1		Nessler tube stand, for 50 ml. tubes.	29070-B	S-21075	7-065
2	2	1	Wire gauze, 4 inches.	19970-A	S-85335	15-590
2	2	1	Triangles, 2-1/2 inches.	19735	S-82415	15-280
2	2		Tripod with concentric rings.	19775-B	S-82515-B	15-305
2	2	1	Tongs, 9 inches.	19600	S-82115	15-200
2	1		Camels Hair Brush, medium, 14 m.m. brush.	10938-B	S-9725	3-654
2	2	2	Brushes, flask, for 500 ml. flasks.	10985	S-9965-B	3-570
2	2	2	Brushes, tube.	10966C	S-9985	3-573
2	2	2	Brushes, tube.	10966A	S-10005	3-576

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
12			Vacuum tubing, 1/4" bore, (feet).	18204-C	S-73535	14-173
24	24	12	Rubber tubing, 1/4" bore, (feet).	18202-C	S-73525	14-159
12	12	6	Rubber tubing, 1/8" bore, (feet).	18200	S-73505	14-158
1	1	1	Corks, bags of assorted sizes, 3 to 16.	12404	S-23055	7-785
1	1	1	Cork borer, size 6 to 11 m.m. (set).	12465	S-23175	7-845
1	1	1	Rubber stoppers, assorted (pounds).	18153	S-73305	14-130
4	4	2	Filter paper, 9 c.m. (boxes).	13255	S-32915	9-795
2	2	1	Filter paper, 12.5 c.m. (boxes).	13255	S-32915	9-795
1	1		Filter paper, quantitative, 9 c.m. (box).		S-32785	9-915
12	6	2	Glass marking pencils, red.	14015	S-65775	13-380
			Hydrogen Ion Comparators			
1	1	1	pH Comparator, Hellige, pocket colormetric, w/color discs and indicators for pH ranges 4.0-5.6, 5.2-6.8, 6.0-7.6, 6.8-8.4, & 8.0-9.6.	21409	S-41765	11-507-20

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
1	1	1	Chlorine residual color disc and orthotolidine reagent for test of 0.0-1.0 p.p.m. residual for use with Hellige pocket comparator.	29175		11-507-30
			Bacteriological			
1			Microscope, monocular, Bausch & Lomb.	61053X	S-52080	12-310
24	24		Pipettes, 1.1 ml., capacity graduated at 1.0 ml.	24115-2	S-60025	13-669B
24	24		Pipettes, 11 ml., capacity graduated at 10 ml.	24115-8	S-60045	13-669J
30	30		Culture dishes with covers, 100 m.m. x 15 m.m.	44370-4	S-25925-B	8-747
1	1		Culture tubes, large, 7" x 7/8" (Gross).	44500-11	S-79525	14-925
1	1		Vials for large culture tubes (Gross).	44500-11	S-79525	14-925
1	1		Culture tubes, small, 6" x 3/4" (Gross).	44500-10	S-79525	14-925
1	1		Vials for small culture tubes (Gross).	44500-10	S-79525	14-925
1	1		Thermometer, Centrigrade, 0° to 110°.	19255	S-80305	15-005
1			Glass slides, 25 m.m. x 75 m.m. (Gross).	66310	S-58785	12-550

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
1			Cover slips (Gross).	66510-B	S-58715	12-524
1			Lens, reading glass - 4".	60410-D	S-44505	12-070
1	1		Counter, tallying machine.	73320	S-23285	7-905
1	1		Counting apparatus		S-23395	7-925
2	2		Culture dish holder.	44398	S-26055	3-460
2	2		Pipette Sterilizing boxes, Copper, 2-1/2" x 16".	46670	S-69815	3-465
2	2		Test tube support.	19200-A	S-79005	14-770
4	4		Test tube basket	48515-B	S-79925	14-971
1	1		Double Boiler, 2 qts.		S-8225	2-750
1			Inoculating needle holder.	46220	S-62765	13-093
1			Forceps, cover glass, cornet.	66600	S-35195	10-295
1			Inoculating needles, (24 B & S gauge) (package), Chromel.	46210B	S-62755	13-095
1			Lens paper (quire).	12290	S-44325	11-996
			Microscopical			
1			Sedgewick rafter filter.	29030	S-84015	15-400
24			Cloth disks to support filter sand.	29034	S-84025	15-415
1			Counting cell.	29038	S-84045	15-425
12			Cover glass.	29039	S-84055	15-430
1			Eye piece micrometer disc, Whipple.	29037	S-84065	15-435

Quantity Type of Plant A	B	C	Description	Catalog Number Central Scientific Co.	E. H. Sargent Co.	Fisher Scientific Co.
			Books			
1	1	1	Standard methods of Water Analysis, latest edition, A. P. H. A. & A. W. W. A.			
1	1	1	Laboratory Manual for Chemical and Bacteriological Analysis of Water and Sewage -- Eldridge, Theroux and Mallman, latest edition, McGraw Hill Co.			

STANDARD SOLUTION FOR WATER ANALYSIS ACCORDING TO AMERICAN PUBLIC HEALTH ASSOCIATION STANDARD METHODS OF WATER ANALYSIS, EIGHTH EDITION, 1936

Platinum–Cobalt Standard, Color 500	200 ml.
Standard Calcium Chloride Solution	500 ml.
Standard Soap Solution	1,000 ml.
Standard Ferric Iron Solution	500 ml.
Standard Silver Nitrate	500 ml.
Soda Reagent	1,000 ml.
Acid Sulphuric, N/50 Solution	1,000 ml.
Sodium Hydroxide, N/50 Solution	500 ml.
Sodium Hydroxide, N/44 Solution	500 ml.
Potassium Thiocyanate	500 ml.
Acid Hydrochloric Dilute, Approximately 3 N	500 ml.
Potassium Permanganate, Approximately N/5	500 ml.
Acid Nitric, 6N Solution	500 ml.
Methyl Orange Indicator	500 ml.
Penolphthalein Indicator	500 ml.
Erythrosine Indicator	500 ml.
Potassium Chromate Indicator	100 ml.
Orthotolidine Indicator	500 ml.
Sodium-meta-arsenite 0.5% Solution	500 ml.

CULTURE MEDIA FORMULAE OF STANDARD METHODS OF WATER ANALYSIS

Bacto-Nutrient Agar, Dehydrated	1 lb.
Bacto-Lactose Broth, Dehydrated	1 lb.
Levine's-Eosin Methylene Blue Agar, Difco	1/4 lb.

BACTERIOLOGICAL STAINING SOLUTIONS ACCORDING TO STANDARD METHODS OF WATER ANALYSIS

Bismark Brown	1/4 lb.

Carbol Fuchsin	1/4 lb.
Carbol Gentian Violet	1/4 lb.
Gram's Iodine Stain	1/4 lb.
Methylene Blue, Koch's	1/4 lb.
Safranin Stain	1/4 lb.
Potassium Iodine	1/2 lb.

NOTE: For Class A plants, chemicals should be bought in bulk and standard solutions and reagents prepared by the plant chemist. In many instances this may apply to Class B plants.

APPENDIX III - TYPICAL DESIGN ANALYSES FOR WATER-SUPPLY SYSTEMS

Table of Contents

The following typical design analyses illustrate the application of capacity factors, per capita allowances, domestic requirements, fire demands, etc., in determining capacity of various components entering into the design of water-supply systems:

1. EXAMPLE NO. 1.

Camp or base with Population of Three Thousand (3,000). Water from wells expected to yield 200 g.p.m. each; water requires no treatment.

a. Required Demand.

Effective population = 3,000, capacity factor = 1.3.

Daily per capita allowance = 100 gallons.

Fire flow = 1,000 g.p.m. for 2 hours.

Design population = 3,000 x 1.3 = 3,900.

3,900 x 100 = 390,000 gallons per day = 271 g.p.m. average rate

b. Well Requirements.

As number of wells should be based upon 16 hours operation per day, two wells each yielding 200 g.p.m. will supply the required demand. Wells should be equipped with 200 g.p.m. minimum pumps discharging directly into the water-distribution system. Both pumps should have electric-motor drive and one unit should also have gasoline-engine drive.

c. Storage Requirements.

Domestic requirements = 50% of 390,000 = 195,000 gallons.

Fire demand = Fire flow + 50% of average domestic rate = 1,000 g.p.m. for 2 hours + $\frac{271}{2}$ x 60 x 2 = 136,260 gallons.

As domestic requirements govern, provide elevated storage with a capacity of approximately 195,000 gallons.

Note: If both well pumps are provided with gasoline-engine stand-by power, then the amount of storage can be reduced to 25% of 390,000 gallons or 97,500 gallons. The fire demand is 136,260 gallons. The output from wells during fire period = 2(200 x 2 x 60) = 48,000 gallons.

Available water = 97,500 + 48,000 = 145,500. This is greater than the fire demand and the reduction in storage from 195,000 gallons to approximately 100,000 gallons would be satisfactory.

d. Water-Main Sizes.

Fire demand = 1,000 + $\frac{271}{2}$ = 1135 g.p.m.

Peak domestic demand = 271 x 2.5 = 678 g.p.m.

Fire demand governs in determining pipe sizes.

2. EXAMPLE NO. 2.

General Hospital with a Capacity of One Thousand (1,000) Beds. Water will come from municipal system, and will be capable of supplying 700 g.p.m. through a short supply main with adequate pressure at the hospital.

a. Required Demand.

Hospital capacity = 1,000 beds.

Equivalent resident personnel = 60% of 1,000 = 600.

Effective population = 1,000 + 600 = 1,600; capacity factor 1.3.

Daily allowance = 150 gallons per bed and 100 gallons per resident personnel.

Fire flow = 1,000 g.p.m. for 4 hours.
1,000 x 1.3 = 1,300 and 600 x 1.3 = 780.

Design population = 1,300 x 150 + 780 x 100 = 273,000 gallons per day = 190 g.p.m. average rate.

b. Storage Requirements.

Domestic requirement = 50% of 273,000 = 136,500 gallons.

Fire demand = Fire flow + 50% of average domestic rate = 1,000 g.p.m. for 4 hours + 190 x 60 x 4 = 262,800 gallons.

Fire demand governs. Assuming that elevated storage is constructed with supply line from city connected to the distribution system with elevated tank floating on the system so that water from the city is available at a rate of 700 g.p.m. during fire periods then the required storage can be reduced by 700 x 60 x 4 or 168,000 gallons. 262,800 - 168,000 = 94,800. Therefore 100,000 gallons of storage will be required.

c. Water-Main Sizes.

$$\text{Fire demand rate} = 1{,}000 + \frac{190}{2} = 1095 \text{ g.p.m.}$$

Peak domestic rate = 190 x 2.5 = 475 g.p.m.

Fire demand rate governs.

3. EXAMPLE NO. 3.

Cantonment and Warehouse Area for Infantry Divisions with Effective Population of Twenty Eight Thousand (28, 000). Surface water will come from nearby creek.

a. Required Demand.

Effective population = 28, 000 Capacity factor = 1.01.

Design population = 28, 000 x 1.01 = 28, 280.

Per capita allowance = 100 gallons.

28, 280 x 100 = 2, 828,000 gallons per day = 1, 960 g.p.m. average.

To meet this demand, a filtration plant with pumping stations and appurtenances having a rated capacity of 3.0 m.g.d. would be provided.

b. Storage Requirements.

Fire flow for one fire in cantonment area requiring 1, 000 g.p.m. for 4 hours or one warehouse fire requiring 2, 000 g.p.m. for 4 hours.

Fire in warehouse area would require 480, 000 gallons.

Fire demand = Fire flow + 50% of average domestic demand.
= 480, 000 + 1960 x 60 x 4 = 715, 200 gallons.

Domestic requirements = 50% of 2, 828, 000 = 1, 414, 000.

c. Domestic Storage Requirements.

(Domestic requirements govern in this case).

At least 50 percent of total storage should be elevated.

Two 500,000-gallon elevated tanks and 500,000-gallon clear well at the filtration plant, or three 250,000-gallon elevated tanks and a 750,000-gallon clear well at the filtration plant should be provided.

d. Filtration Plant.

The plant will be designed with four 0.75 m.g.d. filters assuming reinforced concrete units were used, or six 0.5 m.g.d. filters if wood-tub-type filters were adopted. Filter areas should be based upon a flow rate of 2 gallons per square foot per minute.

e. Raw-Water Pumping Station.

The following pumps should be provided:

Two 2,100 g.p.m. electric-motor-driven pumps.

One 1,050 g.p.m. electric-motor-driven pump.

One 1,050 g.p.m. gasoline-engine-driven pump.

Note: If available, a single dual-powered, 1,050-g.p.m. pump may be substituted for the two 1,050-g.p.m. pumps listed above.

f. High-Service Pumping Station.

Pumps with similar capacities and power as those for raw-water station should be provided.

g. Water-Main Sizes.

Sizes will be governed by a study of peak domestic and fire-flow rates. The peak domestic demand is greater than the fire-demand rate although the latter is more concentrated. Therefore, both domestic and fire flows must be considered in determining water-main sizes. Peak demands for water will be supplied by a combination of pump outlet and withdrawal from storage.